An Analysis of Polyethylene Coating Corrosion in Oil and Gas Pipelines

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Abstract: The corrosion of pipelines' coatings is one of the main problems in oil and gas industries for which a large amount of money is spent each year. Coating is the first defense line in front of a corrosive environment in which pipes have been buried. Good function of coating depends on its adhesiveness rate to the metal surface. Initial adhesiveness and its durability in the contact conditions are among those factors that enhance coating efficiency in long term. The rate of Initial adhesiveness has a high relationship with coating movement and surface wetness by this movement in the course of applying the coating and also with cleanliness and preparedness of pipe surface. The durability and permanence of adhesiveness depends on coating properties including its resistance in front of moisture penetration. Applying coating on the pipelines has a high cost so for this reason the selection and application of coating is of high importance. Also for underground buried pipes it is not possible to change their coatings in short durations unlike other structures. Therefore the coating must be durable for 20 years. This article proceeds to investigate the reason for corrosion in steel pipes with three poly ethylene layers.
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1. Introduction

The corrosion of pipelines' coatings is one of the main problems in oil and gas industries for which a large amount of money is spent each year. Cessation of production creates a very high loss in terms of hydrocarbon production or maintanence costs. Therefore equipment faultless during their shelf life is considered as a basic problem .Those studies which result in compilation of effective strategies, laws, protocols and methods for preventing and removing corrosion effects are studied as ;corrosion management;. Corrosion problem in Canada has resulted in ten times pipelines' leakage and twelve times explosions in the period of 1977 to 1996, and in our country investigating this phenomenon and its management is of extraordinary higher importance due to the fact that oil, gas and petrochemical industries have been located in corrosive environments.

The reports of malfunctions due to corrosion indicates that the reason for this phenomenon is mainly due to tragic carelessness in plumbing and equipment manufacture and installation which result in explosion, fire and spread of toxic materials in living environment. besides it has some costs such as replacement of corroded equipment, shut down of plants due to replacement of corroded equipment, disturbance in processes due to equipment corrosion and impurity of processing products due to corrosion –related leakage and waste of the products of those vessels which are attacked by corrosion, all of these problems make the most important costs and losses created by corrosion. The studies show that 70 percent of losses can be prevented by observing related principles and instructions. According to the report of Bartel institute one third of industries 'corrosion costs are prevented by simple applying of existing knowledge and technology. Another point which is ignored is that indirect corrosion damages are much more than direct ones.Corrosion management has the responsibility of corrosion control and installations in all respects for preserving capital and always uses advanced tools and methods in enhancing this purpose.

Corrosion process is managed since the very beginning of planning installation until their servicing by corrosion manegement.For example a planning engineer gathers enough information from corrosion management to design structures with long and useful shelf life or amends the following work steps by using enhanced information from occurred corrosions.

2. Under Coating Corrosion Mechanisms

Under Coating Corrosion is started in presence of water and oxygen. When water and oxygen are present on the surface of a metal, corrosion occurs due to metal dissolution (anodic effect). This chemical process is balanced by oxygen reduction. Under Coating Corrosion rate depends on the kind of insulation, the amount of oxygen, the amount of impurities in the water, temperatures and the heat transfer properties of metal surface or the conditions of metal surface being wet or dry. In the abscence of oxygen the amount of corrosion rate can be ignored .Although low alloy and carbon steels

have the lowest corrosion rate in alkali environments but chloride ions create localized pitting under coating. If sulphur and nitrogen acids having acidic properties penetrate in to insulation through impurities of water and air or if water has acidic property, general corrosion occurs. Sometimes impurities of water and air specialy nitrate ion (NO3) cause external stress corrosion cracking (SCC) in unstrained carbon or low alloy steels. The phenomenon is more pronounced when intermittent wetting and drying of environment cause the development of impurity concentration.

2.1. Corrosion Control Methods

Corrosion in industries is controlled by one of the following methods.

A-Corrosion-resistant alloys
B- Corrosion inhibitors
C-Stabilization method
D- Corrosion-resistant alloys

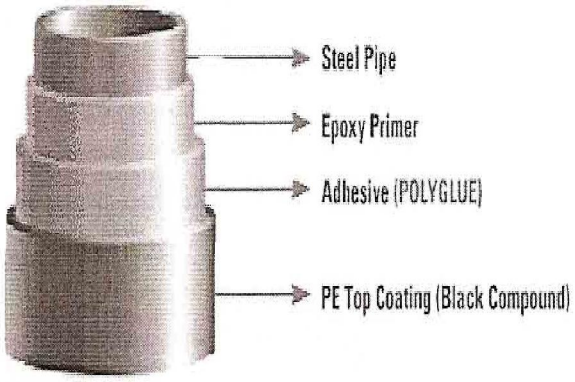

Figure 1: A view of steel pipe with three fold cover.

3. Coatings and their roles in country's economy and industry.

It is quite clear that any of the coating systems have their own adventages and limitations, and that is why one of them is preferred over the other in most of the conditions. But in most other conditions both two systems can be used and it makes selection difficult. In these occasions there must be a suitable method for investigation and comparison that is a reliable guide in selecting proper system. One of the important factors in selecting proper system is cost. The importance of cost factor is such that it is dominant over other parameters and cause selection of a system based on cost. The coating of pipelines exposes a lot of items during operation such as moisture, pressure, bacteria and etc…..

Applying coating over pipelines has a lot of costs, for this reason selection of coating is of much importance.

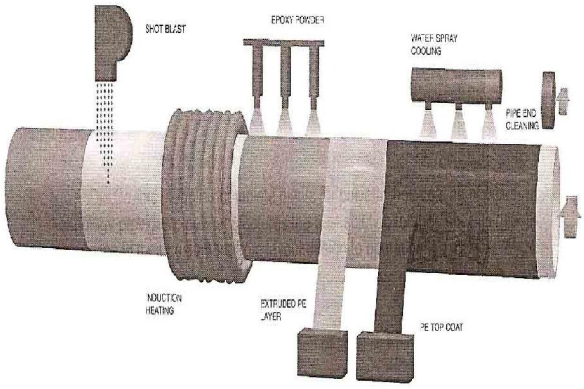

Figure2: View of cover process

Also for buried pipes underground there is the possibility that their coating must be replaced in short durations like other structures and the coating must last at least for more than 20 years. For this purpose the properties a coating needs is as follows:

1-Resistant against water and moisture: even dry soils have a little moisture and pipeline coating is often wet, for this reason coating mustn't absorb moisture because it results in weight increase and electrical resistant reduction.

2- Resistant against variable pressures: placement of pipes under ground results in pipes being under pressure. Also the presence of gravel, movement of soil due to moisture and also other existing particles in the soil causes the above mentioned variable and unharmonious pressure. In fact coating must be a physical protection and not separate from surface.

3- Resistant against bacteria and mushrooms: There are a lot of bacteria in the soil which attack different materials and cause their extinction. Of course bacteria and mould attack is not so prevalent.

4- Resistant against water capillary effect: Water penetration due to capillary effect causes separation of coating from steel. Any fine crevice or gap causes the capillary effect unless the contact between coating and pipe is strong and very sticky. In fact primer color has the duty of creating a strong adhesiveness between pipe and coating and prevents water penetration and coating separation.

5-Suitable with temperature variations: Temperature variations can be influential because the rate of steel expansion and coating is different. Expansion and shrinkage result in movement in the pipe but this movement is uniform and slow. For this reason coating must be resistant against temperature variations and not separated from the pipe.

6- Resistant against being solved: Water is capable of solving some of the materials but the

coatings are insolvable in water. Also it must be investigated that coating be resistant against other solvents besides being insolvable in water specialy against oil and its derivatives.

7- Resistant against absorbing soil: Soil may absorb some materials. Clay, silica gel, charcoal and some other combinations have the absorbing property. Soil always is completely in the contact with coating and absorption of some elements from coating by the soil may make coating fragile, perforated or reduce its resistance against soil.

8- Resistant against mechanical damages: besides the aforesaid items in part 2, coating must be resistant to mechanical stresses during installation or storage.

3.1. First layer

Immediately after the pipe one form of film of liquid or gum of epoxy is created. Minimum dryer thickness must be between 20-60 micron. Based on ISO 2808, epoxy powder has some materials which are used against heat that is used for three-layered poly ethylene coatings for steel pipes and must be specially formulated and designed and this is for electrical application and corrosion improvement from coating system and also providing unlimited cathode maximum resistance is suitable. Epoxy powders used in three –layered coatings is classified in two different groups. The first group has primer property and the second group has coating quality.

These two materials have remarkable differences in applying, temperature and thickness; there is a tendency in industries to use epoxies with coating quality .Epoxy layer must have such an enough thickness that prevent holiday formation. priences and experiments done in the field indicates 40 holiday in 40 feet for a layer with the thick ness of 150 micron.

According to Dennis Neal, the manager of Harding and Neal Company of USA having experience in coatings and corrosion recommends minimum thickness of 250 micron for the epoxy layer. Time is a sensitive and critical factor in creating adhesive and poly ethylene layers. First the adhesive develops a very strong chemical bond with chemical groups in epoxy powder which is uncure therefore into this stage the epoxy must not completely cured. On the other hand adhesive and poly ethylene are connected physically which is done by rollers' pressure and time being critical and sensitive is because of epoxy for bond with adhesive must not completely cure on one hand and must get jelly condition on the other to be able to resist against rollers' pressure, in the other words all operations of these steps are done in less than a second.

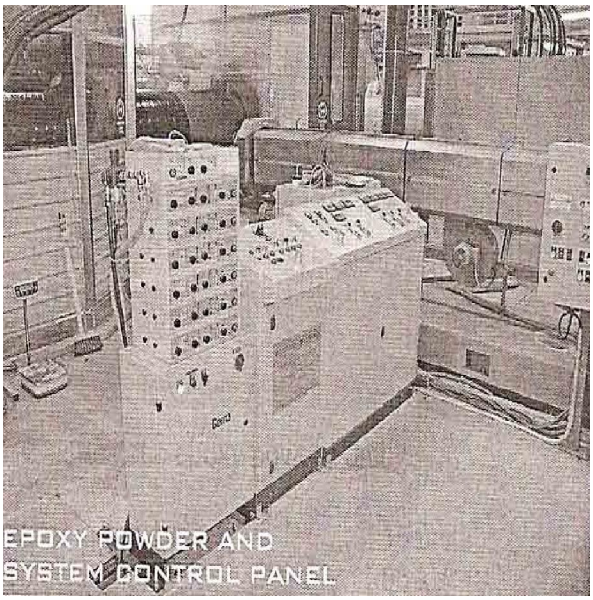

Figure 3: view of epoxy controller.

Coating appliers must be careful that applying a solution for three-layered coating dosent result in another problem for example separation in the seams is reduced by lowering applying temperature of epoxy from 239.4 'C to less than 232.2'C, but although FBE is cured in lower temperature, high viscosity of molten in this temperature dose not allow epoxy flow and complete wetting of metal surface and this causes adverse effect on coating adhesiveness in warm condition and moisture anh extra catholic voltage . The following is Dennis Neal's opinion about this matter obtained from experts:

i) The FBE layer is under cured because the application temperature is low to allow the adhesive to chemically bond to FBE.

ii) There is no adhesion between the FBE and adhesive because the temperature is higher and the FBE is fully cured before the adhesive is applied.

3.2. Second layer

Second layer polymer creates adhesiveness between layers 1 and 3 and must be compatible with both layers. Minimum thickness must be between 160-200 micron. Thickness may increase or reduce according to the mutual agreement with customer but minimum thickness must be investigated safely.

Table 1: Physical properties of adhesive.

PROPERTY	UNIT	VALUE
1)Density	g/cm^3	0.900-0.950
2)Melting index (2.16 kg/190˚C)	g/10min	0.5-8 or as suitable for application as PE (top coat)
3)Elongation	%	95 (min)
4)Melting point	˚C	
5)Co monomer content	%	9 (Typical)

Note: The test for raw epoxy power properties is under the responsibility of manufacturer.

3-3-Third layer

Polyethylene coating must be formed in this layer. Thickness must be uniform in all through the pipe and minimum general thickness must be acceptable.

4. Conclusion

Generally a lot of national capital is spent for corrosion costs in the country. By a short glance on other countries' experiences it is observed that most of the countries have invented ways to prevent corrosion-related damages and applied them.

Corrosion experts in America have felt that there is a basic need for conducting studies to estimate metal corrosion costs incured by America's economy and to prepare a strategy to reduce corrosion-related costs. In this vein according to the dialogues between National America Corrosion Engineers (NACE) and members of transportation ministry, a plan was submitted for the cost of corrosion in 21 century which was accepted in 1998.In 2001 corrosion cost project was submitted in America that in this report direct corrosion cost was estimated by analysis of 26 sections of industry which had a complete information about corrosion.

Finally the total direct cost of corrosion in America was estimated to be 276.000.000.000 dollars in a year. Also an indirect cost of corrosion was equal to direct costs. Most of the experts in the country believe that we need abasic movement in preparing complete formal statistics about corrosion at first so that the dimensions of corrosion are specified in all industries. In the next step we can force industries to consider a series of least corrosion in their management by preparing a preventive strategy for controlling corrosion with the help of assembly. Preventive strategy may be as follows:

1-Developing the awareness about the high cost of corrosion and potentials of cost reduction

2-Changing this wrong attitude that nothing can be done for reducing corrosion costs.

3-Changing policies, rules, standards and management excercies to reduce corrosion costs by corrosion effective management.

4-Enhancing instruction and skills of employees to identify corrosion control methods.

5-Reviewing the procees of designing products to prevent corrosion costs increase.

4.1. Strategies for corrosion management

Corrosion management proceeds to offer preventative strategies in two technical and no technical domains. The topics of no technical domain as preventative strategies are as follows:

1-Enhancing the employees' awareness about the high costs of corrosion and saving costs result in correct applying of existing technologies and corrosion costs. Thus a lot of corrosion problems are due to lack of awareness about corrosion management and accountability of people in exchanging operations, inspection and maintenance of management system.

2- Changing guidelines, protocols, standards and management methods to reduce corrosion costs by correct corrosion management resulting in effective control of corrosion and safe operation and increase in shelf life of equipment.

3-Amending and generalization of employees' instruction to introduce and identifying corrosion control.

4-Changing and amending wrong belief about not being able to do anything about corrosion and making new decisions in preventing this phenomenon. Also preventive strategies in technical domains are of a very high importance. Some of these strategies are as follows.

A-Upgrading planning methods and using advanced planning ones to better managing corrosion which prevents avoidable corrosion costs.Inthis vein planning methods must change and the best corrosion technologies must be available for planners.

B-Improving corrosion technologies via research and development. Corrosion can be controlled in most industries by using scientific methods and new technological achievements.

4.2. An analysis of reasons for three-layered poly ethylene coating separation.

Good function of coating depends to a high extent to its adhesiveness rate to metal surface. Initial adhesiveness and its durability in contact condition are of those factors that result in high efficiency of coating in long term. The extent of initial adhesiveness has a very high relationship with coating flow and its wetting when applying coating

and also with cleanliness of surface and its readiness. Durability of adhesive depends on coating properties such as its resistance against moisture penetration and also its endurance against cathodic disbandment.

The most leading coatings having more consumption than other kinds are as follows:

1-FBE (fusion bonded epoxy)

2-Poly urethane (from technical view poly urethane materials are of the best coatings used since 1970 on).High cost of this coating has resulted in using it just for special cases such as when temperature is very high. Three-layered poly ethylene coating includes epoxy, adhesive and poly ethylene.

Any of the layers provides coating with properties to lengthen its efficiency for a long term. Epoxy layer has a very good adhesiveness due to its transverse bonds and has a very high resistance against corrosion and oxygen penetration. But it is vulnerable to the mechanical hit when storing and line performance. Poly ethylene layer is a very good protection to prevent physical damages. A main problem with this coating is that poly ethylene does not have adhesiveness with the metal and for this reason an adhesive layer being a kind of reduced polymer is used for pasting poly ethylene to epoxy.

4.3. Main factors in coating separation are as follows:

1-The manner three-layered poly ethylene coating (quality) of applying coating in the factory

2-ExposurConditions and properties

Three-layered poly ethylene is one of these coatings with high efficiency, although it seems that it is used in the field in a very limited extent (comparing other coatings) and more laboratory studies and field experiences are needed to investigate if they have aforesaid properties.

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